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THE LIGULATE WOLFFIAS OF THE UNITED STATES.

BY CHARLES HENRY THOMPSON.

Of the Lemnaceae, represented in our flora by *Lemna*, *Spirodela*, and *Wolffia*, the Wolffias present two very marked forms designated by Hegelmaier as subgenera — *Euwolffia* and *Wolffiella*.* In our species these are characterized by small granular symmetrical fronds for the first, and comparatively large, thin, strap-like unsymmetrical fronds for the latter. *Euwolffia* is represented by two species, both of which are known to be fertile. *Wolffiella*, however, has never been known to produce flowers. Though there is no doubt that it belongs to this order, yet there is a question whether it is properly a *Wolffia*. My observations lead me to consider *Wolffiella* a good genus, as has been suggested,† with structural characters intermediate between the Wolffias proper and the Lemnas, but this distinction could hardly be recognized as conclusively generic without the support of generic differences in their flowers, which latter it is hoped will yet be discovered as their habitats are more thoroughly explored. This subgenus has heretofore been reported as having but one representative in the United States, and that a variety of a Mexican species, growing in the subtropical region of Florida.

Since this variety and another Mexican species have both only recently come under my notice — both from new localities with us — it seems fitting that a careful report be made on them from the facts which I have been enabled

* Hegelmaier: Die Lemnaceen, pp. 122, 131.

† J. D. Smith: Bull. Torr. Bot. Club, VII. 65.

to glean from a study of them, and it is with a view to add these to the general knowledge of Lemnaceae that I append the following notes.

WOLFFIA GLADIATA FLORIDANA, J. D. Smith.

During the past summer the Garden received from the collector, Mr. B. F. Bush, a small package of aquatic plants, mostly of the order Lemnaceae, collected in the swampy region of southeastern Missouri. These plants reached the Garden in good healthy condition and were immediately placed in a tank where they continued to thrive,—affording no little interest to many visitors.

Later it was thought advisable to separate the species into different vessels, and in doing this my attention was attracted to a number of little clusters of minute ribbon-like green bodies floating about free just beneath the surface of the water, which at first glance might easily have been mistaken for algae, but, when examined under the microscope, revealed a much higher type of organized tissue. As no fruiting bodies could be detected, some difficulty was experienced in determining in just what part of the vegetable kingdom these little organisms belonged, but at length they were identified with *Wolffia gladiata Floridana*, J. D. S.,* of the order Lemnaceae.

The typical *Wolffia gladiata*, Hegelm.† is a native of Mexico, at present reported only from the City of Mexico, where it grows abundantly in pools and ditches with kindred aquatics.

Our variety *Floridana* differs from the specific form in proportionally longer and narrower fronds, which are curved more to saber-form. Hegelmaier, the author of the species, in a letter to Capt. John Donnell Smith says, in comparing them: "Had both forms come to my knowledge at the

* Bull. Torr. Bot. Club, VII. 64 (1880).

† Hegelmaier: Die Lemnaceen, p. 133 (1868).

same time I should probably have taken the Florida plant for the type of the species inasmuch as it is constant with itself wherever you have found it; and the Mexican plant would have been treated as a var. *abbreviata*.* "

The habit of growth seems to vary according to the nature of its surroundings. In still water it collects in dense masses as intricately interwoven as the fibers of felt, while in flowing water it is more likely to be scattered — united only in small clusters which might aptly be termed families, since from the youngest up to the oldest plant each individual is attached by its stipe to the parent. These families take on a peculiar form. Each frond has a pronounced double curve — the curve edgewise of a saber and again curved sidewise as a part of a band. The young, growing from the pouch of the parent, continues in the direction of the band-like curvature of its parent so that at maturity the two form an almost regular semicircle. These each send out other young fronds which retain the curvature of their parents but are growing edge to edge with them. This multiplication is continued until an almost complete hemisphere is produced † (pl. 64, f. 9). Directly at the upper pole this hemisphere is exposed to the air at the surface of the water, and at this point also, it will be readily seen, the base of each frond is situated. This grouped formation (families) seems to be adapted to catch any slight current arising from a disturbance of the water, for if the water is agitated these inverted basket-like bodies take on a rolling, rocking motion which sinks and carries them to a considerable distance where again they come to the surface. This seems to be their mode of travel or dissemination — a sort of subaquatic tumble weed. From the curved form of the tips of the fronds it is easily seen how two or more

* Bull. Torr. Bot. Club, VII. 65 (1880).

† Looking from above, the curvature seems to be uniformly downward and to the right, though I would hesitate to make such a statement definite without further observations.

such families coming in contact would readily interlock and thus form the beginning of a mat of the plant at the surface. This mat would be intensified as the young fronds push their curved tips downward through the mass and lock the families in closer embrace. This will account for the dense masses found in many places.*

The individual plant itself is an elongated strap-like frond, about fifteen times as long as the broadest part and but a few cells in thickness, tapering from the oblique base with its broad pouch-cleft to a narrow rounded apex which is only about $\frac{1}{4}$ to $\frac{1}{3}$ as broad. The margin is entire. As stated in the introduction, the flowers and fruit of this plant are not known, but it reproduces quite freely by a form of branching or budding. At the basal end of each frond the two epidermal layers are split apart to form a deep elongated triangular pouch which extends about $\frac{1}{7}$ to $\frac{1}{5}$ the length of the frond (pl. 64, f. 7). At the bottom of this pocket, in the acute angle, the budding takes place which results in new individuals being cast off to take up a life's work in themselves. The young frond grows out from the pouch-opening in the same general direction as its parent, until of about the same length, when it takes a position at about right angles to its parent, by which time it also is sending out a young frond. In fact a frond is scarcely more than half matured before it begins to form buds in its pouch, while at the same time its parent is sending out other individuals — sister fronds — alongside it. Each frond is attached to its parent by an elongated stipe which is long persistent, thus holding individuals together for many generations, forming the families above referred to (pl. 64, f. 6).

In structure the frond consists of the two epidermal layers separated in the greater part of its length by large air chambers and united only at the margins and a small portion of its apex. They are connected in the cavernous

* John Donnell Smith: Bull. Torr. Bot. Club, VII. 64 (1880).

part by chains of cells which form the side walls of the air chambers. These air chambers are usually hexagonal, as are also the epidermal cells — both slightly elongated in the direction of the longer axis of the frond. Uniformly scattered over both surfaces are pigment cells which differ from the surrounding epidermal cells in their smaller size and thicker walls and their yellowish-brown color and the granular appearance of their contents (pl. 64, f. 8.) The stipe, at the point where it was formerly attached to the parent plant, is composed wholly of chains of elongated prismatic cells which spread out fan-like toward the body of the frond, and in so doing present all gradations of cell-form from the prismatic at the stipe scar to the regular hexagonal form of the epidermis; however a few chains of the elongated cells extend unbroken to the base of the pouch where the budding takes place, and here connect with the stipes of the offspring, thus forming continuous chains throughout the generations. They too contain pigment cells. In this species this bundle of chains, or "costa," as Smith terms it, seems to occupy a position at the left side of the pocket — looking from above — within the line of juncture of the two walls of the pouch.*

The finding of this variety adds an interesting item to the geographical distribution of plants, since heretofore it is reported only from a few stations in Florida, yet in the light of recent discoveries of many representative Florida plants — *Leitneria Floridana*, etc, — growing in the swampy regions of southeastern Missouri, it is not surprising that the list should receive additional genera.

The plants examined were collected in Dunklin County, Missouri.— By Mr. B. F. Bush, from the Varner river near

* Here arises the question whether the stipe is always to the left or not. This I have found to be true in all my examinations of living material, though they were too limited to venture a positive assertion to that effect. Dry plants could give me no aid on this point since in them it seems impossible to determine which is the upper and which the lower surface of the frond.

Kennett, July 27, 1895, growing with *Lemna Valdiviana*, *L. minor*, *Spirodela polyrrhiza*, *Wolffia Brasiliensis* and *Azolla Caroliniana;* By Dr. O. Widmann, from the St. Francis river, October 5, 1895,— received at the Missouri Botanical Garden, adhering to the roots of *Jussiaea repens*.

WOLFFIA LINGULATA, Hegelm.

While on a brief visit in California during the past fall, one day late in September I discovered among other Lemnaceae growing in an irrigation canal an abundance of what afterward proved to be *Wolffia lingulata*, Hegelm. On October 7, 1895, I collected a large quantity of this mixture of aquatic plants which, with a little care, I was enabled to bring to St. Louis in good living condition and place in the Missouri Botanical Garden, where it has since continued to grow luxuriantly — affording abundant material for study, both for observations of growth habits and for anatomical investigations.

Wolffia lingulata, Hegelm. is a much shorter and broader species than the foregoing and, as its name indicates, is tongue-shaped. Like *W. gladiata* it is curved in the direction of a band but, unlike it, is not curved edgewise. It differs also in never forming the dense interlaced masses that *gladiata* does. This is impossible from the short and broad shape of the fronds. The young frond readily breaks away from its parent even before fully grown, so that no family grouping is ever found either. In the numberless specimens I have examined I have never yet found more than two * fronds united — the parent and offspring — though

* These observations were made on normal plants with normal conditions surrounding them. Later I found in one of my fish-globes, where I have my plants growing, a few instances of *three* fronds united, but this seems to be due to the fact that the plants had not been disturbed for several weeks, for the slightest handling readily broke the three apart. The plants of this globe were not in a healthy condition either — being kept in another greenhouse of different temperature and humidity from the others. However, the rule as stated above holds true for the plants as they are found in their natural growth.

younger fronds in all stages of development are to be seen in the pouches of both of these, wholly included within them. Again I have failed to find an instance where two fully grown fronds were connected — the offspring completing its growth after being set free and scarcely mature when it in turn casts its offspring. How many individuals one parent frond may give rise to I am unable to state, though I have observed as many as four in their various stages of development, all attached to the same matrix, which probably continues to successively develop more.

As before stated, the frond grows in a band-like curve, but instead of being flat as in *gladiata* it has the lateral margins at maturity upturned like the sides of a boat (pl. 65, f. 6). In these, too, the shape seems to be adapted for catching water currents and thereby being carried to distant points. When the water is disturbed the plants dive in all directions from the surface, and from their peculiar form assume a somersault or rotary motion — the direction of least resistance for their shape — then slowly rise to the surface again.* This power to float is due to the abundance of large chambers in the tissue of the basal portion of the fronds, filled with some gas (pl. 65, f. 5).

Wolffia lingulata was named and described by Dr. Friedrich Hegelmaier,† from material collected in Mexico by Louis Hahn in 1868. The plant is a thin frond, tongue-shaped and entire, with a rounded apex and a slightly oblique truncated base, which is split horizontally to form a triangular pouch, in the basal angle of which the budding of reproduction takes place (pl. 65, 1–5). This basal

* Another agency in so distributing the plants is a little crustacean much resembling a sand-flea. It swims to the surface and there attaches itself to the under surface of a frond. This added weight slowly sinks both to the bottom where the animal releases the frond and both again come to the surface — the frond appearing in a new locality, the animal to repeat its sportive manoeuvers.

† Hegelmaier: Die Lemnaceen, p. 132 (1868).

angle is seldom less than 60° or greater than 90°, making the pouch shallow as compared with the foregoing species. The budding takes place from a slightly elongated placenta or matrix situated on the upper surface of the lower wall of the pouch, and the young buds are produced in regular order from near the pouch angle (pl. 66, f. 2–6).

In developing, the young frond does not retain the same line of direction in growth as the parent assumes — the long axis of each crossing at an angle ranging between 160° and 175°. In all the specimens examined, looking at the upper surface in each case, the young frond was turned to the right, away from the stipe scar of the parent, which is, in every case, on the left-hand side and under the young frond. The proportional distance of this scar from the two marginal angles of the pocket varies slightly, but in no case did I find it so near the left-hand angle as to warrant the drawings of Hegelmaier* which show it at the left-hand juncture of the upper and lower walls. He also figures the rows of elongated cells which form the costa as being situated in this line of juncture and extending from the scar to the basal angle of the pocket. My observations have shown the costa to be situated within the lower wall of the pouch, about one-fourth the width of the pouch from the left-hand angle formed by the juncture of the two walls and never coinciding or parallel with it. In younger plants the stipe scar and costa are nearer the angle and in older plants they are farther away (pl. 66, f. 7–9).

In structure the plant is made up primarily of an upper and a lower plate of epidermal tissue, each composed of a single layer of cells. The plates are united at the margins of the frond and connected in the interior by walls of upright cylindrical cells (pl. 65, f. 7). These walls are but one cell thick and one cell high toward the margin

* Hegelmaier: Die Lemnaceen, t. iv. f. 31, 32 — (1868); Fl. Bras. fasc. 76, pl. I. f. iii. f. 1, 2, 4, 5 — (1878).

but two cells high in the interior. The large cavities formed by these walls and the two epidermal layers are termed "air cavities" by Hegelmaier, and the gas they contain enables the plant to float. This cavernous tissue extends from one-half to two-thirds the length of the frond, from the base. After a long, careful search I was unable to find any openings connecting these cavities with the exterior, so it is hardly probable that the gas in them is free to circulate with the air at the surface of the water. All searches for stomata were fruitless.

The epidermal cells are usually hexagonal and slightly elongated in the direction of the long axis of the frond. The air cavities are of the same shape and similarly lengthened. Both the upper and lower walls of the pouch are two cells thick except in the costa, which is increased to several cells in thickness. In the stipe and costa the cells are much elongated, prism-form with either square or wedge-shape ends, arranged in chains. From the point where the stipe joins on the frond these chains of elongated cells spread out flabelliform and the cells gradually shortening and broadening merge into the regular hexagonal form in the epidermis (pl. 65, f. 9). However, a few chains go direct to the base of the pocket and there join, through the matrix, with the stipes of the young fronds, forming a continuous chain of these ligneous-like cells throughout the generations (pl. 65, f. 11). In view of this fact the costa perhaps ought properly to be considered the axis of the plant and the frond merely as epidermal tissue modified to perform the functions of obtaining and utilizing food.

Quite regularly distributed over both surfaces are epidermal cells, somewhat smaller than those surrounding them, with granular yellow contents; they occur also in the elongated cells of the costa. These are the so-called pigment-cells of Hegelmaier. Their function is as yet unexplained (pl. 65, f. 8).

The occurrence of this species in this isolated point, far away from its first reported habitat, separated from it by

high ranges of mountains and connected with Mexico by water only through the Pacific Ocean, brings up the interesting question as to how it came to be there. How is it disseminated otherwise than by water currents? The most probable theory seems to be that the plants were carried from their southern home,— considering Mexico their original habitat,— on the feet of migratory aquatic birds. This is very plausible from the fact that if one's finger is thrust into a mass of the plants, as they are floating on the water, and then withdrawn, scores of plants will be found adhering to the surface of the finger. This is probably the case also with the legs and feet of ducks and geese. These birds, rising from the lakes of the region of central Mexico, where *Wolffia lingulata* is reported as growing in abundance, may start on their long northward journey, and their feet folded among the feathers would afford a considerable protection to a number of plants which might otherwise be dried to death by the rapid passage of the bird through the air. Wherever the bird might stop to rest in northern lakes, or streams, some of these plants would be washed away from it and, if the climatic conditions were favorable, would continue their natural growth. However, it is highly probable that later these plants will be found to occur at many intermediate points between the City of Mexico and the Californian locality, in which case the exposure to the air in the migration of birds would not necessarily be of so long duration. In either case the plants must have come over the high range of mountains to the south of the newly reported habitat.

My plants were found about three miles west of Bakersfield, California, in what is known as the Emery canal or Artesian ditch. Concerning this canal, my brother, W. O. Thompson, of that place, writes on Feb. 2, 1896: "Its origin is similar to that of an artesian well. The water comes from the Kern river; but it goes down through the coarse sand and rises again some distance from the river. The ditch went dry last season." Associated with

the *Wolffia* was an abundance of *Lemna Valdiviana minima*, Hegelm., and a lesser quantity of *Lemna minor* L.

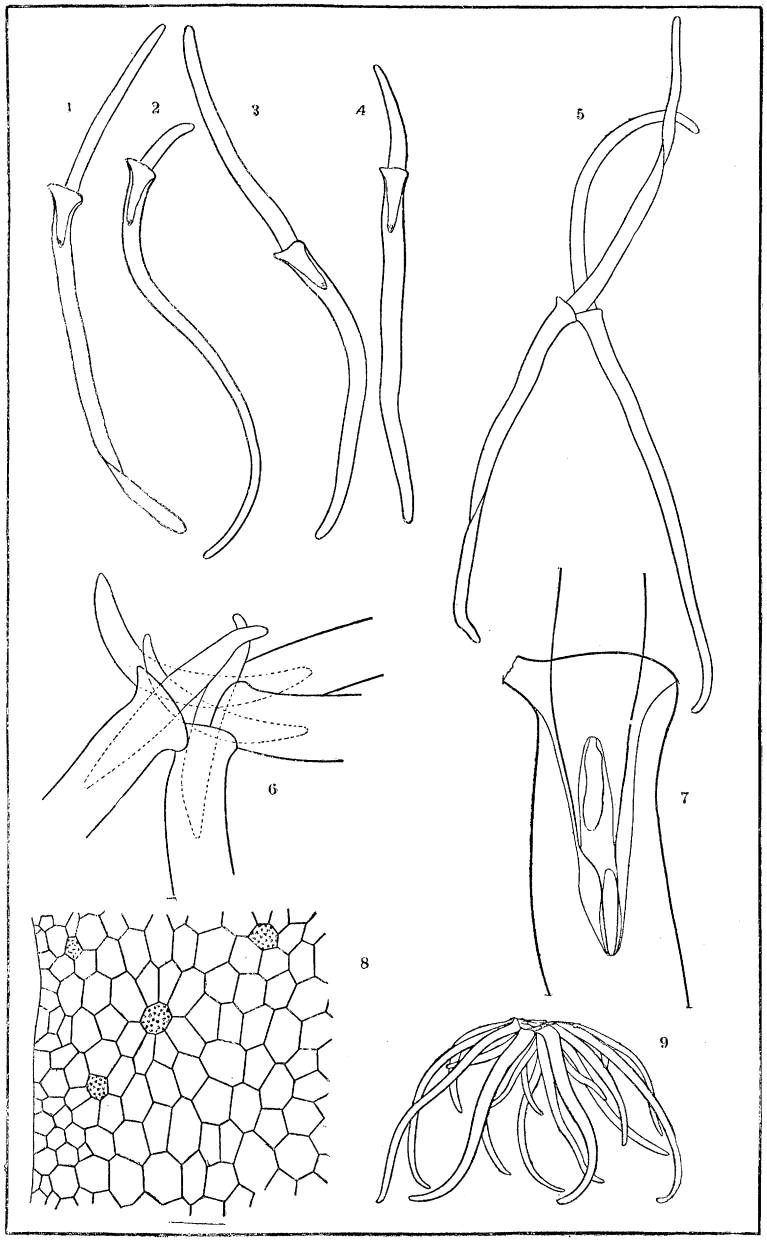
EXPLANATION OF PLATES ILLUSTRATING THE LIGULATE WOLFFIAS OF THE UNITED STATES.

The figures were drawn by Miss Grace E. Johnson from sketches prepared by the author.

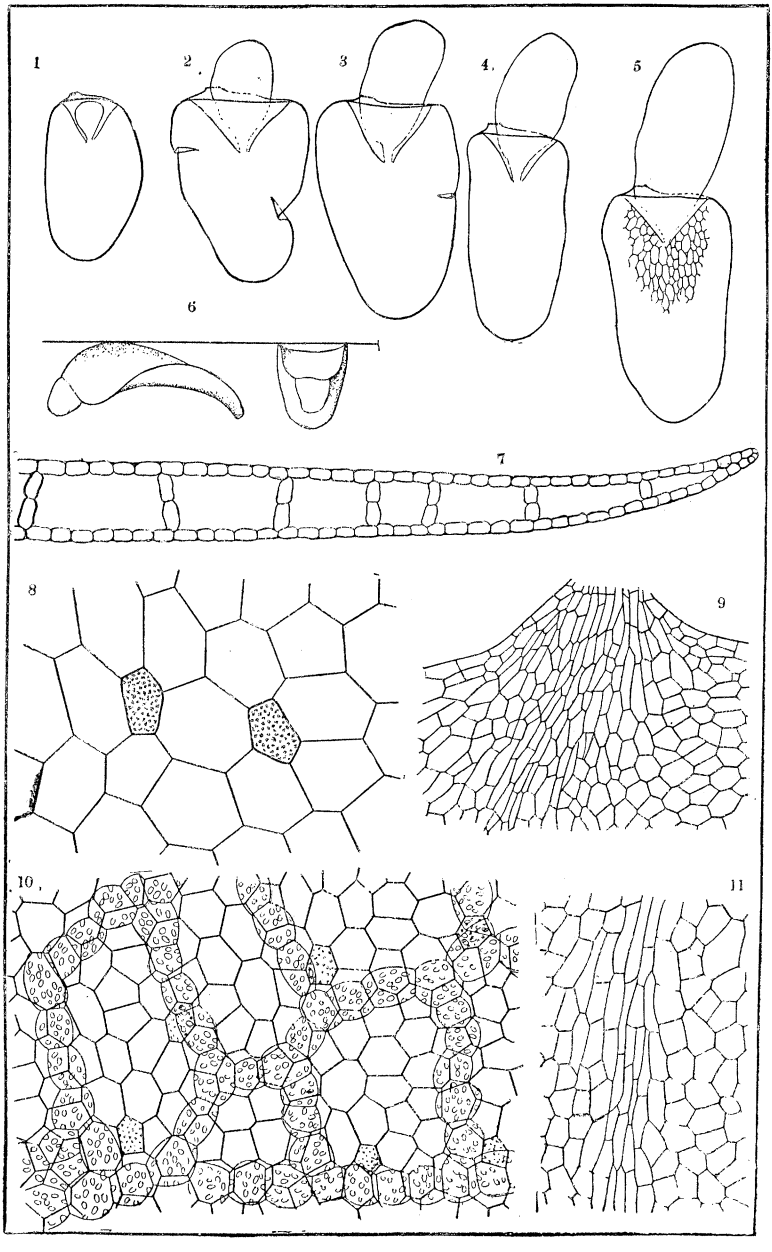
Plate 64. *Wolffia gladiata Floridana* J. D. S.— 1, 2, 3, 4, 5, Mature plants with offspring, × 8; 5, three generations of fronds attached; 6, bases of a group of attached fronds showing the formation of so-called "families;" 7, base of frond showing the pocket with two offspring attached to its matrix, the older of which also has a young individual in its pocket, × 36; 8, a portion of the upper epidermis next the margin showing epidermal cells with pigment cells, × 145; 9, a group ("family") of plants, × 5.

Plate 65. *Wolffia lingulata* Hegelm.— 1, A frond just separated from its parent, × 8; 2, 3, 4, 5, frond showing variations in shape and line of direction in growth of young fronds, × 8; 5, shows position and relative size of air cavities; 6, normal position of fronds in water, × 5; 7, portion of transverse section of frond showing epidermal layers, partition walls and air cavities, × 125; 8, portion of epidermal tissue showing two pigment cells, × 320; 9, stipe scar and end of costa, × 75; 10, epidermal cells showing general form and relatively smaller pigment cells. Beneath are shown chains of cells forming walls of air cavities — chlorophyl grains drawn in these to better bring out these partition cells, × 200; 11, portion of costa about midway between stipe-scar and basal angle of pouch, × 75.

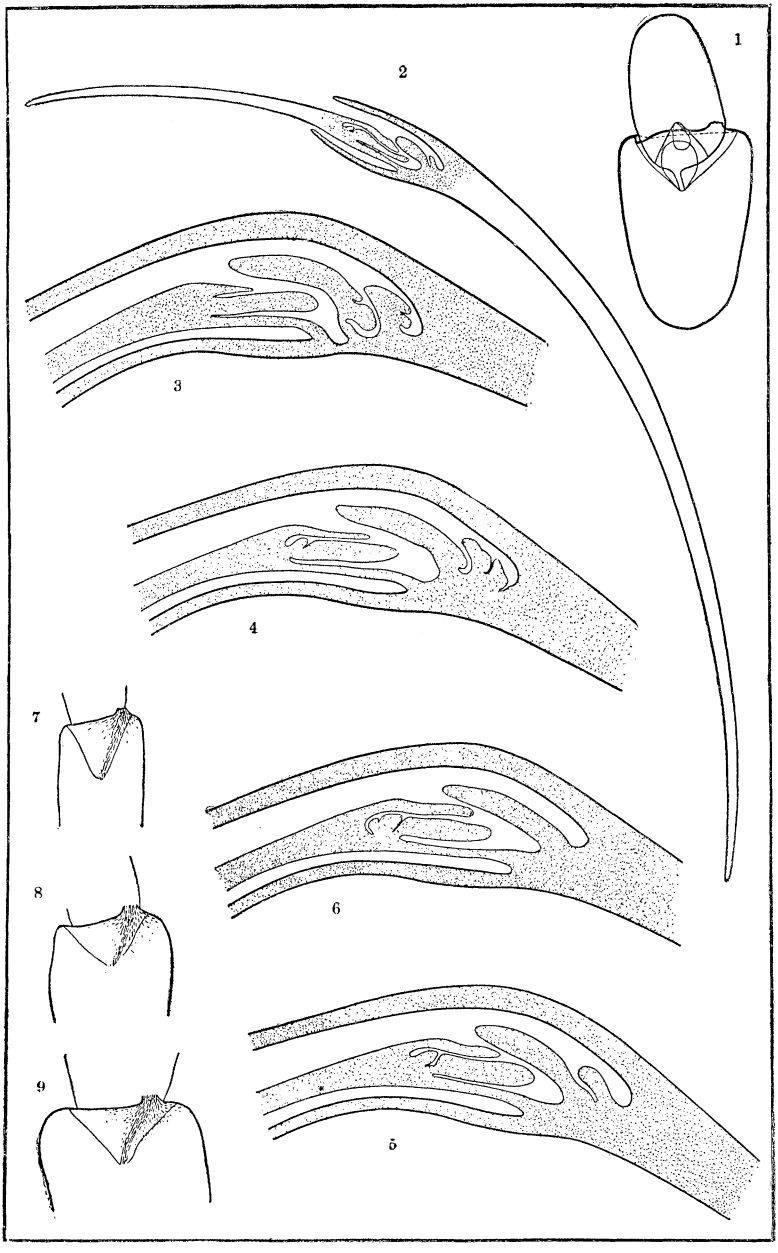
Plate 66, *Wolffia lingulata* Hegelm.— 1, Plant showing offspring in various stages of development and their respective positions, under surface, × 8; 2, longitudinal section of plant through the reproductive pouch showing position of offspring from a lateral view, × 16; 3, 4, 5, 6, a series of longitudinal sections through the reproductive pouch like last but more enlarged, × 125; 7, 8, 9, diagrams representing the position of stipe and costa, also transition of prismatic cells,— under surface of frond, × 8.



WOLFFIA GLADIATA, VAR. FLORIDANA.



WOLFFIA LINGULATA.



WOLFFIA LINGULATA.